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PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

MISSOURI HEADWATERS BASIN
ESTLER LAKE DAM
BEAVERHEAD COUNTY, MONTANA
MT-824

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PREPARED FOR:

HONORABLE TED SCHWINDEN
GOVERNOR, STATE OF MONTANA

RATTLESNAKE RESERVOIR COMPANY
(OWNER/OPERATOR)

PREPARED BY:
HOSKINS-WESTERN-SONDEREGGER, INC.

APRIL, 1981

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EXECUTIVE SUMMARY

Under contract with the Seattle District Corps of Engineers and with representation from the State of Montana Department of Natural Resources and Conservation, Estler Lake Dam was inspected by Hoskins-Western-Sonderegger, Inc., on 19 September 1979, under the authority of Public Law 92-367. Estler Dam is located in Beaverhead County, Montana, approximately 20 miles northwest of Dillon.

This report was compiled from information obtained during an on-site inspection, a review of operation records, and analysis of hydrologic and hydraulic data. Findings were compared to engineering criteria currently accepted by most private and public agencies engaged in dam design, construction, and operation.

PRINCIPAL FINDINGS AND EVALUATIONS

Estler Lake is located in the Beaverhead National Forest and is operated under a special-use permit from the U. S. Forest Service. It is used for irrigation storage and for recreation. The project consists of a natural lake and an earth and masonry dam to raise the lake elevation for irrigation storage. The reservoir has a drainage area of approximately 3.5 square miles, a surface area of approximately 48 acres at the spillway crest, and storage at the dam crest of approximately 620 acre-feet.

In accordance with the "Recommended Guidelines for Safety Inspection of Dams" (Ref. 1), the 35-foot-high Estler Lake Dam (MT-824) is classified as being of small size and as having a significant (Category II) downstream hazard potential, due to the presence of approximately 2 inhabitable structures downstream from the dam. Discharges from a breach of Estler Lake Dam would reach these structures after passing through Kelley Reservoir, located approximately 3.5 miles downstream from Estler Lake, which would be unable to prevent Estler Lake discharge from reaching these structures.

Inspection criteria (Ref. 1) recommend that a small-sized project with a significant downstream hazard potential be capable of safely handling a spillway design flood (SDF) in the range of the 100-year flood to one-half of the probable maximum flood (PMF). The PMF is the flood expected from the most severe combination of meteorologic and hydrologic conditions that are reasonably possible in the region. Because of the involved risk, we recommend that this project be capable of safely handling one-half of the PMF.

During the dam safety analysis, an estimated PMF was developed for the drainage basin resulting from the 24-hour probable maximum precipitation (PMP). The resulting PMF has a volume of approximately 2850 acre-feet. The reservoir level at the beginning of the 24-hour storm was assumed to be at the spillway crest elevation. Reservoir routings of the estimated 24-hour PMF indicate that the project will handle approximately 7% of the PMF volume before overtopping if the low-level outlet is fully closed or

approximately 10% of the PMF volume before overtopping if the low-level outlet is fully open. The dam is constructed of materials that will erode and fail when overtopped by floodwaters. Such failure could endanger lives and cause considerable property damage. On the basis of the field inspection and the study of hydrologic and operational data, Estler Lake Dam does not conform to the recommended guidelines with respect to discharge and/or storage capacity to safely handle the recommended SDF.

Seepage was found at the downstream toe for the entire length of the dam, suggesting a high phreatic surface. The downstream embankment face is very steep, and evidence of embankment or foundation piping (boil) was noted. No piezometers are installed to measure water levels. There is no internal drainage system. It is our judgment that conditions described in this report indicate that the dam does not conform to the recommended guidelines (Ref. 1) with respect to the stability of the downstream slope.

PRINCIPAL RECOMMENDATIONS

Due to the availability of storage between the normal pool and the dam crest, the present project provides a degree of flood protection to the downstream area. The intent of report recommendations is to maintain or improve project safety, if feasible, without decreasing this existing flood protection.

Develop and immediately place into operation a downstream warning plan, for use in the event of possible embankment failure. Establish and follow a formal maintenance plan. Inspect the control gate, trash rack, outlet conduit, and inlet structure and repair as necessary. Remove all bushes and root systems from the dam and spillway and adequately repair any resulting holes. Remove debris from the dam and spillway.

Conduct more-detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity. Modify the project as studies indicate. Conduct embankment stability analyses and modify the project as studies indicate.

Prior to performing engineering studies and remedial construction, coordinate all work with the U. S. Forest Service and the State of Montana Department of Natural Resources and Conservation to insure compliance with all pertinent laws and regulations.

Stephen H. Nickel
Professional Engineer

PERTINENT DATA

1. GENERAL

Federal Identification Number	MT-824
Owner/Operator	Rattlesnake Reservoir Company
Purpose	Irrigation storage and recreation
Location	Sec. 29, T5S, R11W, Beaverhead County, Montana
Watershed	Estler Creek
Downstream Hazard Potential	Significant (Category II)
Size Classification	Small
USGS Quadrangle	Torrey Mountain, Montana Ermont, Montana

2. RESERVOIR

Surface Area at Normal Pool (Spillway Crest)	48 acres
Normal Storage (Spillway Crest)	470 acre-feet
Total Storage (Minimum Dam Crest)	620 acre-feet
Surcharge Storage	150 acre-feet
Drainage Area	3.5 square miles
Reservoir Water Surface Elev. (9-19-79)	7859.0 feet (NGVD)

3. SPILLWAY

Type	Uncontrolled earth and rock channel
Crest Elevation	7859.4 feet (NGVD)
Crest Width	11 feet
Spillway Capacity (Minimum Dam Crest)	285 cfs

4. OUTLET WORKS

Type	Controlled, corrugated metal and reinforced concrete conduit with trash rack at upstream end
Controls	Flat-back, metal slide gate with manual control from dam crest
Size	2-foot-wide x 3-foot-high reinforced concrete arch top conduit and 24-inch-diameter CMP
Length	40 feet CMP and 79 feet reinforced concrete arch conduit

4. OUTLET WORKS (Cont.)

Inlet Invert	7835.0 feet (NGVD)
Outlet Invert	7828.0 feet (NGVD)
Normal Tailwater	Unknown
Discharge Capacity (Minimum Dam Crest)	92 cfs

5. DAM

Type	Earth fill and masonry
Maximum Hydraulic Height	35 feet
Crest Length	465 feet
Minimum Crest Elevation	7863.1 feet (NGVD)
Crest Width	Varies from 19 feet to 44 feet
Upstream Slope	1(V) on 1.5(H)
Downstream Slope	1(V) on 2(H) for upper 7 feet; Rock masonry wall below that point with average slope of 1(V) on 0.5(H)

CHAPTER 1

BACKGROUND

1.1 INTRODUCTION

1.1.1 Authority and Scope

This report summarizes the Phase I inspection and evaluation of Estler Lake Dam, owned and operated by the Rattlesnake Reservoir Company of Dillon, Montana.

The National Dam Inspection Act, Public Law 92-367 dated 8 August 1972, authorized the Secretary of the Army, through the Corps of Engineers, to conduct safety inspections of non-federal dams throughout the United States. Pursuant to that authority, the Office of the Chief of Engineers issued "Recommended Guidelines for Safety Inspection of Dams" (Ref. 1) in May 1975.

The recommended guidelines were prepared with the help of engineers and scientists, highly experienced in dam safety, from many federal and state agencies, professional engineering organizations, and private engineering consulting firms. Consequently, the evaluation criteria presented in the guidelines represent the comprehensive consensus of the engineering community.

Where necessary, the guidelines outline a two-phased study procedure for investigating and evaluating existing dam conditions so deficiencies and hazardous conditions can be readily identified and corrected. The Phase I study is:

(1) a limited investigation to assess the general safety condition of the dam;
(2) based upon an evaluation of the available data and a visual inspection;
(3) performed to determine if any emergency measures and/or additional studies, investigations, and analyses are necessary or warranted; and
(4) not intended to include extensive explorations, or analyses, or to provide detailed alternative correction recommendations.

The Phase II investigation includes all additional studies necessary to evaluate the safety of the dam. Included in Phase II, as required, should be additional visual inspections, measurements, foundation exploration and testing, materials testing, hydraulic and hydrologic analyses, and structural stability analyses.

The authority for the Corps of Engineers to participate in the inspection of non-federally owned dams is limited to Phase I investigations with the exception of situations of extreme emergency. In these cases the Corps may proceed with Phase II studies, but only to the extent needed to answer serious questions relating to dam safety that cannot be answered otherwise.

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The two phases of investigations outlined above are intended only to evaluate project safety and do not encompass in scope the engineering required to perform design or corrective modification work. Recommendations contained in this report may be for either Phase II safety analyses or detailed design study for corrective work.

The responsibility for implementation of these Phase I recommendations rests with the dam owner and the State of Montana. It should be noted that nothing contained in the National Dam Inspection Act, and neither any action nor failure to act under this Act shall be construed (1) to create liability in the United States or its officers or employees for the recovery of damage caused by such action or failure to act; or (2) to relieve an owner or operator of a dam of the legal duties, obligations, or liabilities incident to the ownership or operation of the dam.

1.1.2 Purpose

The purpose of the inspection and evaluation is to identify conditions that threaten public safety, so that they may be corrected in a timely manner by non-federal interests.

1.1.3 Inspection

The findings and recommendations in this report were based upon visual inspection of the project, as well as interviews with owners and/or knowledgeable residents. Records of infrequent inspections and correspondence dating as far back as 1903 were available for review. Construction sketches of limited detail from the last major dam reconstruction (1963) were also provided. Inspection procedures and criteria were those established by the "Recommended Guidelines for Safety Inspection of Dams" (Ref. 1).

Personnel present during the inspection included:

Louis Boitano, Civil Engineer, Seattle District Corps of Engineers; and
Art Taylor, Civil Engineer, State of Montana, Department of Natural Resources and Conservation.

Hoskins-Western-Sonderegger, Inc. personnel who participated in the field inspection and contributed to this report are:

Stephen H. Nickel, Geotechnical Engineer, Team Leader;
Michael McMeekin, Hydrologist/Hydraulics Engineer; and
Gene Holtorf, Hydrologist/Hydraulics Engineer.

This report has been reviewed by representatives of the Rattlesnake Reservoir Company, the Montana Department of Natural Resources and Conservation, the USDA Soil Conservation Service (SCS), and the U.S. Forest Service. Their written comments have been included in the Appendix of this report.

1.2 DESCRIPTION OF PROJECT

1.2.1 General

Estler Lake Dam (MT-824), owned and operated by the Rattlesnake Reservoir Company under a special-use permit from the U.S. Forest Service, forms an irrigation and recreation impoundment. The dam is located on Estler Creek, a tributary of Rattlesnake Creek, in Section 29, T5S, R11W, Beaverhead County, Montana, approximately 20 miles northwest of Dillon. Estler Lake has a drainage area of approximately 3.5 square miles, surface area of approximately 48 acres and storage of approximately 470 acre-feet at the spillway crest elevation of 7859.4 feet, and maximum storage of approximately 620 acre-feet at the minimum dam crest elevation of 7863.1 feet. The spillway, located approximately 20 feet south of the left (north) dam abutment, is an uncontrolled earth and rock channel discharging to Estler Creek (see Photos 9, 10, and 11). The irrigation, or low-level, outlet works consist of a trash rack and inlet structure with a manually controlled slide gate and a composite conduit through the embankment composed of a 24-inch-diameter corrugated metal pipe leading to a 2-foot-wide by 3-foot-high concrete arch pipe. The slide gate is inclined, with a control wheel at the dam crest (see Photos 12, 13, and 14). The outlet works are located approximately at the mid-point of the dam.

Estler Lake Dam is an earthfill and masonry structure that is approximately 35 feet high and impounds approximately 620 acre-feet at the minimum dam crest elevation. Based on visual reconnaissance and engineering judgment, approximately 2 inhabitable structures could be affected by a breach of Estler Lake Dam. These structures are located along Rattlesnake Creek below Kelley Reservoir, which is approximately 3.5 miles below Estler Lake Dam. Discharge from a breach of Estler Lake Dam could also cause Kelley Reservoir to overtop and fail. Estler Lake Dam, therefore, is classified as small in size and has a significant (Category II) downstream hazard potential classification (Ref. 1).

1.2.2 Regional Geology

The Pioneer Mountains lie in the southwest corner of Montana. They are bounded by the Anaconda Range to the north, the Beaverhead Mountains in the Bitterroot Range to the west across the Big Hole Valley, and the Ruby and Tobacco Root Ranges to the east across the Beaverhead Valley.

The Pioneer Mountains are essentially composed of a complex suite of igneous rocks, the Boulder Batholith, which has intruded into the much older sedimentary and metamorphic rocks of the area. The intrusion of the Boulder Batholith, along with intensive block and thrust faulting, has been the major factor in the geologic structure of the Pioneer Mountains. Present topography is the result of Pleistocene glaciation and valley fill in the lower intermountain areas.

The northern Rocky Mountain region, prior to Late Cretaceous time, was essentially a flat plain partially flooded by shallow seas. At the end of the Mesozoic Era, of which the Cretaceous is the last geologic epoch, this

entire area became geologically active. Three things exemplify this activity: (1) Cretaceous uplift; (2) Late Cretaceous thrust faulting; and (3) Late Cretaceous-Tertiary intrusive activity, i.e., the Boulder Batholith. The regional uplifting of the continental crust brougth the earth up in several north-south trending blocks. The west sides of the faulted blocks, or mountains, are higher in elevation and have characteristically abrupt scarps, while the east sides of the blocks have long, gentle slopes.

The uplifted land became subject to erosion. As the sediments were transported downslope, they filled the intermountain valleys with debris ranging from muds and sands to gravels and cobbles. These valley fill sediments attain a depth of several thousand feet in the axis of the mountain valleys.

Pleistocene alpine glaciation of Wisconsin Age (12,000 years before present) sculptured typical alpine glacial features including cirques, headwalls, and troughs in the upper elevations of the Pioneer Mountains. In lower elevations glacial deposits of terrace gravel, stream bed alluvium, landslide rubble, and glacial drift occur.

1.2.3 Seismicity

Estler Lake Dam (MT-824), located in the Pioneer Mountains, lies in Seismic Zone 3 as indicated by the Seismic Zone Map (Ref. 1). The seismic probability of this regional setting is one of potential for major damage and is based on the known distribution of damaging earthquakes in the region.

The Preliminary Map of Young Faults in the United States, by the U. S. Geological Survey (Ref. 2), indicates suspected activity along the northern expanse of the Pioneer Mountains and Holocene activity directly east, along the northwestern side of the Tobacco Root Range. The Geologic Map of Montana shows extensive faulting prior to the Cenozoic Era in the immediate vicinity of Estler Lake in the southern portion of the Pionner Mountains. The Humbolt Anticline, in this vicinity, has produced several lateral faults. The valley of Rattlesnake Creek is the result of one of these faults.

Local earthquakes significant enough to be reported in References 3 and 4 occur in 2 epicentral areas. One of these is to the northeast along a line from 20 miles northwest of Helena to 25 miles north of Bozeman, while the other is to the southeast in northeast Idaho, northwest Wyoming, and the adjoining areas of Montana. Of these two epicentral areas, the one is 75 to 100 miles northeast and the other is 50 to 150 miles southeast of the project site. Two earthquakes of significant intensity which have occurred in the tri-state region southeast of the project site were the Hebgen Lake, Montana, earthquake (8 August 1959), that had an intensity of X (Modified Mercalli), and another southeast of Dillon, Montana, and southeast of the project area (23 November 1947), that had an intensity of VIII. The three largest reported earthquakes northeast of the Pioneer Mountains have had intensities of VIII. One of these earthquakes had its epicenter at a point 25 miles north of Bozeman (27 June 1925), while the other two occurred at Helena (18 October and 31 October 1935).

In the vicinity of the project there have been numerous other earthquakes in this century (Ref. 3 and 4). In an area bounded by the 44th and 46th parallels and by the 110th and the 112th meridians (including the tri-state region), there have been more than 50 earthquakes with intensities of V and more than 10 with an intensity of VI. The closest reported earthquakes to the project site have occurred approximately 50 miles east near Ennis and Virginia City, Montana. The largest of these had an intensity of VI and occurred near Ennis (10 March 1977). The exact distance from the epicenter of this earthquake to the project site is not known.

The Pioneer Mountains lie in a highly seismically active area with the potential for a damaging earthquake. This warrants that special attention be given to the dams in the area that have been constructed without consideration of the effects of earthquakes.

1.2.4 Site Geology

Estler Lake lies in a scoured cirque basin with gentle to moderately concave slopes (10% to 40%) and thin glacial deposition. A thin rock mantle and patchy, shallow, poor to moderately drained, sandy loams and loams characterize the surficial sediments.

The northern portion of the drainage area is characterized by strongly patterned ground on steep and very steep, slightly convex slopes (45% to 70%) with thick regolith and very shallow, excessively drained, loamy sands and sandy loams. This area is windswept alpine turf and talus.

The southwestern headwall is very steep (60% to 80%) with an adjacent strongly scoured glacial troughwall. Mass-wasting features such as talus slopes and rock glaciers are present in this portion of the area.

The entire area is underlain by igneous rock. The dam appears to have been constructed on a terminal moraine; however, more detailed information about site geology (e.g., depth to bedrock) is not known.

1.2.5 Design and Construction History

Records indicate that Estler Dam was originally constructed about 1903. The original special-use permit for the dam and storage reservoir was issued by the U.S. Forest Service in 1915. Numerous repairs and reconstruction were performed from 1915 to 1963, including improvements to the spillway and dam crest to provide and maintain adequate freeboard. Major reconstruction, which was completed in November of 1963, consisted of the following: replacement of the deteriorated vertical control gate with a new inclined slide gate; extension of the outlet conduit; and reconstruction of the upstream slope of the embankment. The Soil Conservation Service (SCS) assisted in the design of the 1963 reconstruction. No major changes have been made since that time. No drawings pertaining to any of the past construction were available.

CHAPTER 2

INSPECTION AND RECORDS EVALUATION

2.1 HYDRAULICS AND STRUCTURES

2.1.1 Spillway

The spillway is located 20 feet south of the left dam abutment and discharges into Estler Creek. The spillway is an uncontrolled, earth and rock channel approximately 11 feet wide across the bottom and 5.6 feet deep at the dam centerline. The channel surface is fairly irregular and is covered with small (2-inch to 6-inch) stones on the bottom and larger boulders along the sides. Small trees and brush are growing in various places within the channel, and some debris is also present. The slope of the channel upstream from the spillway crest is approximately 2%. The channel downstream from the crest varies in slope from 3% to 6% until its confluence with Estler Creek. Approximately 30 feet upstream from the spillway crest is a log boom which appears to be functional in keeping most debris away from the spillway. The spillway channel can be seen in Photos 9 through 11, and the profile and a typical cross section can be seen on Plate 4.

The spillway channel appears to be in generally good condition, with no serious erosion visible despite apparent use. In addition, it appears to offer sufficient protection to the embankment in the event of high spillway discharges.

The discharge rating for the spillway was computed by assuming critical depth at the channel crest and computing water surface profiles upstream into the lake, using a Manning's "n" value of 0.040. The capacity of the spillway varies from 0 cubic feet per second (cfs) at the spillway crest elevation of 7859.4 feet to 285 cfs as the minimum dam crest elevation of 7863.1 feet. A complete discharge rating curve for the spillway is shown on Plate 6.

2.1.2 Outlet

An irrigation outlet is located approximately at the mid-point of the dam. The outlet consists of 40 feet of 24-inch-diameter corrugated metal pipe (CMP) which has been added to the upstream end of a 79-foot-long, reinforced concrete conduit, which has a 2-foot-by-2-foot rectangular base and a 1-foot-radius semi-circular roof. The outlet is controlled by an inclined slide gate located at the upstream end of the conduit, which is operated from the dam crest by a rising stem, handwheel lift. The slide gate mechanism, installed in 1963, appeared to be in good, operational condition, although it was not operated. The concrete structure in which the handwheel is mounted, however, was cracked and spalled. The condition of the upstream portion of the outlet conduit and the trash rack could not be ascertained, as they were under water at the time of the inspection. At the downstream end, the visible portion of the concrete conduit appeared to be in serviceable condition, with some surface erosion but no cracks.

The entire length of the conduit was not inspected. The invert of the upstream end of the conduit was determined, from construction sketches, to be at an elevation of 7835.0 feet or 28.1 feet below the minimum dam crest elevation. The invert of the downstream end of the conduit is at an elevation of 7828.0 feet or 35.1 feet below the minimum dam crest elevation. Approximately 80 feet downstream from the outlet is a metal flow-measuring flume. This flume is in fair condition, having buckled somewhat due to earth pressure. Another 60 feet downstream is a wooden weir which is in extremely poor condition. The irrigation outlet works, the flume, and the weir can be seen in Photos 12 through 17. The capacity of the irrigation outlet, assuming the water level to be at the minimum dam crest elevation, was computed to be 92 cfs. This capacity was based upon full pipe flow in the CMP section and assuming the control gate to be in the fully-opened position. The complete outlet discharge rating curve can be seen on Plate 7.

2.1.3 Freeboard

The normal pool elevation of Estler Lake is assumed to be the crest elevation of the spillway, 7859.4 feet. The vertical distance between the normal pool, or spillway crest, and the minimum dam crest is 3.7 feet. The effective fetch for wind-generated waves is approximately 0.27 miles. The total wave run-up and wind set-up on the embankment is approximately 2.7 feet (Ref. 5). Thus, the vertical distance between the minimum dam crest elevation and the wave height elevation above the normal pool elevation is 1.0 foot. With the surface of the water at the crest of the spillway, 1.0 foot of freeboard above the wave height would probably be adequate protection in accordance with the criteria in Reference 6.

Routings indicate that no freeboard exists during the recommended spillway design flood (see Section 3.1.1).

2.2 HYDROLOGY, CLIMATOLOGY, AND PHYSIOGRAPHY

2.2.1 Climatology and Physiography

The climate of the area around Estler Lake is continental and characterized by a large diurnal and seasonal temperature range. Extreme variability of wintertime temperatures results from frequent occurrence of chinook winds which follow a Pacific maritime air mass invasion. The summers are characterized by warm days, with low humidity, and cool nights. Winters are cold and highly variable in severity from year to year and within a given year.

Dillon, located in Beaverhead County at an elevation of 5218 feet, is the climatological station nearest the damsite. Precipitation and climatological data from this station are not applicable to the damsite because of the 2640-foot elevation difference between Estler Lake and the weather station. The average annual precipitation at Estler Lake is approximately 35 inches (Ref. 7). The average expected date of the first freeze is August 23rd, and the average expected date of the last freeze is July 9th (Ref. 8).

The drainage basin above and including Estler Lake has an area of approximately 3.5 square miles. Other than the main stream (Estler Creek) upon which Estler Lake Dam is built, there are no other developed perennial tributaries draining into the lake. Basin elevations range from the spillway crest elevation of 7859.4 feet to approximately 10,570 feet at the drainage divide. Basin vegetation consists of moderately thick pine and sparse grasses in the lower basin area to sparse pine on extremely rocky surfaces in the upper basin area.

2.2.2 Reservoir Storage and Spillway Discharge

Estler Lake has a surface area of approximately 48 acres and a storage volume of approximately 470 acre-feet at the spillway crest elevation of 7859.4 feet. Storage of approximately 150 acre-feet is available between the spillway crest and the minimum dam crest elevation of 7863.1 feet (see Plate 5). Discharge through the spillway with the water surface at the minimum dam crest is approximately 285 cfs. Discharge through the irrigation outlet under these conditions and with the control gate fully open would be approximately 92 cfs. Complete discharge rating curves for the spillway and irrigation outlet are shown on Plates 6 and 7, respectively.

2.2.3 Estimated Probable Maximum Flood

The probable maximum flood (PMF) is the flood expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. A storm, the intensity of which approached probable maximum precipitation (PMP) intensity, did occur in parts of Montana in June of 1964.

Inspection criteria (Ref. 1) recommend that a small-sized project with a significant downstream hazard potential be capable of handling a spillway design flood (SDF) in the range of the 100-year flood to one-half of the PMF. Because of the involved risk for this project, we recommend that the SDF be one-half of the PMF.

A PMP storm of 24-hour duration was applied to the Estler Lake drainage basin. The 24-hour, 12-hour, 6-hour, and 1-hour PMP depths were estimated from National Weather Service Technical Paper 38 (Ref. 9) to be 15.2 inches, 12.7 inches, 10.5 inches, and 6.5 inches, respectively. All 6-hour increments from 0 to 24 hours, and the hourly increments of the maximum 6-hour increment, were arranged in accordance with criteria in Weather Bureau Hydrometeorological Report No. 43 (Ref. 10).

The PMF was assumed to result from a PMP storm in late spring over frozen ground. Thus, a constant soil loss rate of zero was applied throughout the 24-hour PMP storm, in accordance with Corps of Engineers' recommendations. Thus, the overall configuration of the 24-hour storm is not affected by losses in the soil, and basin rainfall is equal to basin runoff for all storm increments. Direct precipitation onto the surface of the lake was also added in with no losses.

2.2.4 Flood Routing

The level of Estler Lake at the beginning of the 24-hour PMP storm was assumed to be at the spillway crest elevation of 7859.4 feet, corresponding to assumed normal pool conditions. The total volume of the 24-hour PMF for Estler Lake is approximately 2850 acre-feet. Reservoir routings indicate that, with the control gate of the irrigation outlet closed, the lake will handle, through storage and spillway discharge, approximately 7% of the PMF volume before overtopping. With the control gate fully open, the lake will handle approximately 10% of the PMF volume before overtopping.

PMF hydrographs were developed using the SCS dimensionless unit hydrograph. Reservoir routings of the inflow hydrographs were made using the Modified Puls Method. The HEC-1 (Dam Safety Version) computer program (Ref. 11) was used for the hydrograph computations and reservoir routings.

2.3 GEOTECHNICAL EVALUATION

2.3.1 Dam

The 35-foot-high earth and masonry dam is 465 feet long and has a crest width which is generally 19 feet, but increases to 44 feet at the maximum section (see Photo 1). The upstream face is irregular from the crest to the normal pool elevation and has a slope of 1(V) on 1.5(H) below the normal pool elevation. The upper 7 feet of the downstream face is sloped at 1(V) on 2(H). Below this point, there is a rock masonry wall which appears to have been constructed in several stages. Mortar was used for a portion of the wall. The average slope of the rock wall is 1(V) on 0.5(H). The wall is shown in Photos 3, 4, 5, and 6.

Borrow for the embankment appears to have been obtained from borrow pits above both abutments. The material exposed on the crest of the dam and in the borrow areas is a nonplastic silty sand with gravel, cobbles, and boulders, which is highly erodible.

Vegetation on the embankment is sparse, with nothing growing on the crest and approximately 30% coverage of weeds and grasses on the upper portions of the upstream and downstream faces. There are bushes growing on the upstream face near the right abutment and near the spillway approach channel near the left abutment. These bushes are about 6 feet high.

The rock riprap, generally below the normal pool elevation on the upstream face, and the rock used in the downstream rock wall appear to be of igneous origin. All visible rock on the dam appeared unweathered and highly durable. No evidence was found of a granular bedding or filter course between the rock and the silty sand embankment material. The presence of sags or bulges on the upstream face could not be determined because of the irregularity of the embankment. For the same reason, it was impossible to evaluate the adequacy of the riprap coverage. Distress in the downstream rock wall was impossible to determine visually due to the irregularity of the slope and because of what appear to be successive additions to the wall, all having differing slopes.

2.3.2 Foundation Conditions, Seepage, and Drainage

The dam is probably founded on soil similar to that used in its construction. There is clear seepage, at or below the downstream toe, for the entire length of the dam. The flow appears to be greater on the right side of the embankment than on the left. The ground downstream from the downstream toe is saturated for distances ranging from 10 feet to nearly 50 feet downstream from the dam. In the left abutment trough a large ditch, perhaps a former spillway, carries seepage water away from the embankment (see Photo 6). In the right abutment trough, two smaller ditches have been constructed to intercept and divert water from the embankment (see Photo 4). Also in the right abutment trough, wood has been placed on the ground surface along the toe of the wall, apparently to stabilize the ground (see Photo 7). In the left-center of Photo 7, there is an active seepage boil where, although the seepage is clear, material has been deposited after removal by piping from the embankment or foundation. The total seepage quantity below the right side of the dam at the time of the inspection was estimated to be 10 to 15 gallons per minute. The seepage quantity below the left side of the dam is roughly half this amount (5 to 10 gallons per minute).

There was no evidence to indicate that the dam included any type of internal drain, nor are there any piezometers installed in the dam.

2.3.3 Stability

The seepage, which suggests a high phreatic surface, evidence of embankment or foundation piping (boil), and the steeply sloping rock masonry wall forming the lower portion of the downstream slope are all reasons for questioning the stability of the embankment. It is our judgment that the stability of the embankment and the rock wall does not conform to the recommended inspection guidelines (Ref. 1). Additional information is required to adequately evaluate stability.

2.4 PROJECT OPERATION AND MAINTENANCE

2.4.1 General

Operation and maintenance of Estler Lake and Dam is the responsibility of the Rattlesnake Reservoir Company with technical assistance provided by the Forest Service. The original special-use permit specifying these responsibilities was issued in January of 1915. Although a plan for the operation and maintenance of Estler Lake and Dam was not available at this writing, past records and inspections indicate a favorable history of reasonable maintenance and up-keep. Accessibility to the lake and dam is extremely difficult, and visits to the area are probably made no more than a few times each year.

2.4.2 Dam

There is no formal plan for performing periodic maintenance on Estler Lake Dam. Inspection reports and other correspondence indicate a history of

reasonable maintenance from 1915 to the present, but maintenance was performed on an "as needed" basis instead of following a structured plan. The largest current maintenance problem is the improper handling of the seepage through the dam. Debris removal from the dam and reservoir and brush removal from the upstream face of the dam are also current maintenance needs.

2.4.3 Reservoir

As previously mentioned, there is no formal plan for operation and maintenance of Estler Lake, other than the inferred responsibilities in the special-use permit. Generally, the lake is allowed to fill during the fall, winter, and part of the spring. Storage is discharged for irrigation purposes during the growing season.

Despite the lack of a plan, attention to maintenance has been favorable over the lifetime of the dam. The most significant maintenance problem indicated in inspection reports is the periodic accumulation of debris in the lake, along the upstream face of the dam, at the entrance to the spillway, and, occasionally, in the spillway channel itself.

2.4.4 Warning Plan

There is no formal warning plan of action to warn downstream inhabitants or interests in the event of impending dam failure.

CHAPTER 3

FINDINGS AND RECOMMENDATIONS

3.1 FINDINGS

Visual inspection of Estler Lake and Dam, supplemented by analysis of the project in terms of the recommended guidelines' performance standards, resulted in the following findings:

3.1.1 Size, Hazard Classification, and Safety Evaluation

According to the "Recommended Guidelines for Safety Inspection of Dams" (Ref. 1), Estler Lake Dam is classified as small in size with a significant downstream hazard potential rating. The recommended spillway design flood (SDF) for this project is one-half of the probable maximum flood (PMF). The project can control only about 7% of the 24-hour PMF volume. Because the project is incapable of controlling the recommended SDF without overtopping and causing the dam to fail, Estler Lake Dam does not conform to inspection guidelines with respect to storage and/or spillway capacity.

3.1.2 Embankment Dam

As noted in Section 2.3, there is evidence of seepage at the downstream toe for the entire length of the dam. This seepage suggests a high phreatic surface. The seepage, evidence of embankment or foundation piping (boil), and the steeply sloping rock masonry wall forming the lower portion of the downstream slope are all reasons for questioning the stability of the embankment. There are no piezometers or other instruments installed in the dam. Based on experience with similar structures and materials, it is our judgment that the dam does not conform to stability criteria in the recommended guidelines.

3.1.3 Spillway

The uncontrolled earth and rock channel spillway was found to be in good structural condition. There was no serious erosion or sloughing and no significant debris accumulations which could obstruct flow. The major spillway deficiency is the presence of some trees and brush in the channel.

3.1.4 Outlet Works

The irrigation outlet works appeared to be in good, operational condition, although the controls were not operated. The condition of the trash rack and the upstream end of the conduit could not be ascertained as they were under water at the time of inspection. The portion of the conduit within the embankment also could not be inspected. The only noticeable deficiencies were the cracked and spalled concrete on the slide gate control

structure and the eroded but serviceable surface of the concrete arch conduit at its downstream end.

3.1.5 Spillway and Reservoir Capacity

The lake storage capacity and spillway discharge capacity are insufficient to prevent overtopping of the dam during the recommended SDF. This investigation has determined that during the 24-hour PMF storm, the dam can handle approximately 7% of the PMF volume with the control gate closed and approximately 10% of the PMF volume with the control gate open.

3.1.6 Operation and Maintenance

Operation and maintenance are performed by the owners with technical assistance provided by the Forest Service. There is no formal operation plan for the reservoir. Water from runoff is stored in the reservoir and is released from the outlet as needed for irrigation. Consequently, the lake level fluctuates seasonally.

There is no formal maintenance plan for the dam, but the facility has a history of fairly good maintenance.

There is no formal warning plan of action to warn downstream inhabitants in the event of impending dam failure.

3.2 RECOMMENDATIONS

Due to the availability of storage between normal pool and dam crest, the present project provides a degree of flood protection to the downstream area. The intent of the following recommendations is to maintain or improve project safety, if feasible, without decreasing this existing flood protection.

1. Immediately develop, implement, and periodically test an emergency warning plan for use in the event of dam overtopping.

2. Inspect the control gate, trash rack, outlet conduit, and inlet structure and repair as required.

3. Remove bushes and root systems from all embankment surfaces and from the spillway and adequately backfill the resulting holes.

4. Remove and dispose of all debris on the upstream face of the dam and in the spillway.

5. Conduct more-detailed hydraulic and hydrologic studies to better determine the downstream hazard and required spillway capacity. Modify the project as studies indicate.

6. Conduct embankment stability analyses and modify the project as studies indicate. Studies should be conducted by an experienced geotechnical engineer.

7. Develop and implement a periodic maintenance plan for the dam and appurtenant structures. Because of the remoteness of the project site, the maintenance plan should include frequent condition inspections whenever water is impounded above the natural lake level.

8. Establish a program for periodic, comprehensive, safety inspections at no more than 5-year intervals. These inspections should be performed by engineers qualified in the design, construction, operation, and maintenance of earth dams.

Prior to performing engineering studies and remedial construction, coordinate all work with the U.S. Forest Service and the State of Montana Department of Natural Resources and Conservation to insure compliance with all pertinent laws and regulations.

REFERENCES

1. U. S. Army Corps of Engineers, Office of the Chief of Engineers, Report to the U. S. Congress, National Program of Inspection of Dams, Vol. 1, Appendix D, "Recommended Guidelines for Safety Inspections of Dams", Washington D. C., Department of the Army, May 1975.

2. Howard, K. A., et al, "Preliminary Map of Young Faults in the United States as a Guide to Possible Fault Activity," U. S. Geological Survey, Reston, Virginia, 1978.

3. U. S. Geological Survey, "Earthquake Information Bulletin," Washington D. C., 1973-1978.

4. U. S. Department of Commerce, Earthquake History of the United States, Publication 41-1, Washington D. C.

5. U. S. Army Corps of Engineers, Office of the Chief of Engineers, "Wave Run-up and Wind Set-up on Reservoir Embankments," Engineer Technical Letter No. 1110-2-221.

6. U. S. Department of the Interior, Bureau of Reclamation, Design of Small Dams, Water Resources Technical Publication, U. S. Government Printing Office, Washington D. C., 1974.

7. U. S. Department of Agriculture, Soil Conservation Service, "Average Annual Precipitation in Montana," Portland, OR, 1977.

8. Caprio, J. M., "Montana: Average Dates of Freeze," Folders No. 81, 82, and 83, Montana Agricultural Experiment Station, Montana State College, Bozeman, Montana, March 1965.

9. U. S. Department of Commerce, Weather Bureau, Generalized Estimates of Probable Maximum Precipitation for the United States West of the 105th Meridian, Technical Paper No. 38, U. S. Government Printing Office, Washington D. C., 1960.

10. U. S. Department of Commerce, Environmental Science Services Administration, Weather Bureau, Probable Maximum Precipitation, Northwest States, Hydrometeorological Report No. 43, Washington, D. C., November 1966.

11. U. S. Army Corps of Engineers, Hydrologic Engineering Center, Flood Hydrograph Package (HEC-1), Users' Manual for Dam Safety Investigations, Davis, California, September 1978.

(PHOTO 1) Estler Lake Dam, Overview

(PHOTO 2) Upstream Face from Left Abutment

(PHOTO 3) Downstream Face from Right Abutment

(PHOTO 4) Downstream Face near Right Abutment, Seepage Area

(PHOTO 5) Downstream Face

(PHOTO 6) Downstream Face from Left Abutment

(PHOTO 7) Active Seepage Boil, Right Abutment Trough

(PHOTO 8) Concentrated Seepage, Right Abutment Trough

(PHOTO 9) Spillway Approach Channel and Log Boom

(PHOTO 10) Spillway Control Section, Looking Upstream

(PHOTO 11) Spillway Exit Channel, Looking Downstream

(PHOTO 12) Control Works for Low-Level Slide Gate

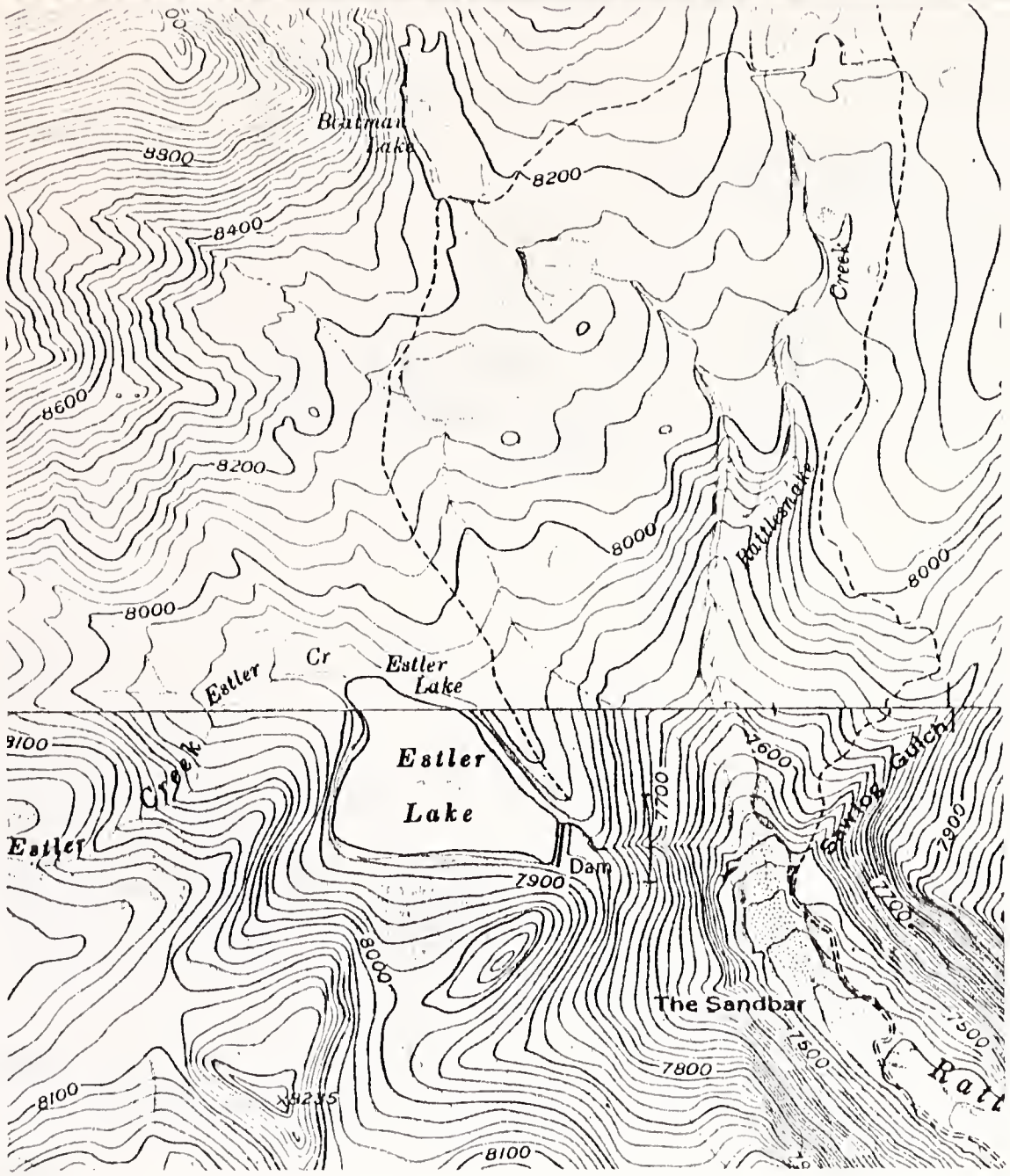
(PHOTO 13) Former Gate Tower and Existing Inclined Gate Stem Location

(PHOTO 14) Conduit Outlet and Downstream Face of Dam

(PHOTO 15) Looking Downstream
from Crest of Dam

(PHOTO 16) Flume below Dam

(PHOTO 17) Weir below Flume



SITE PLAN

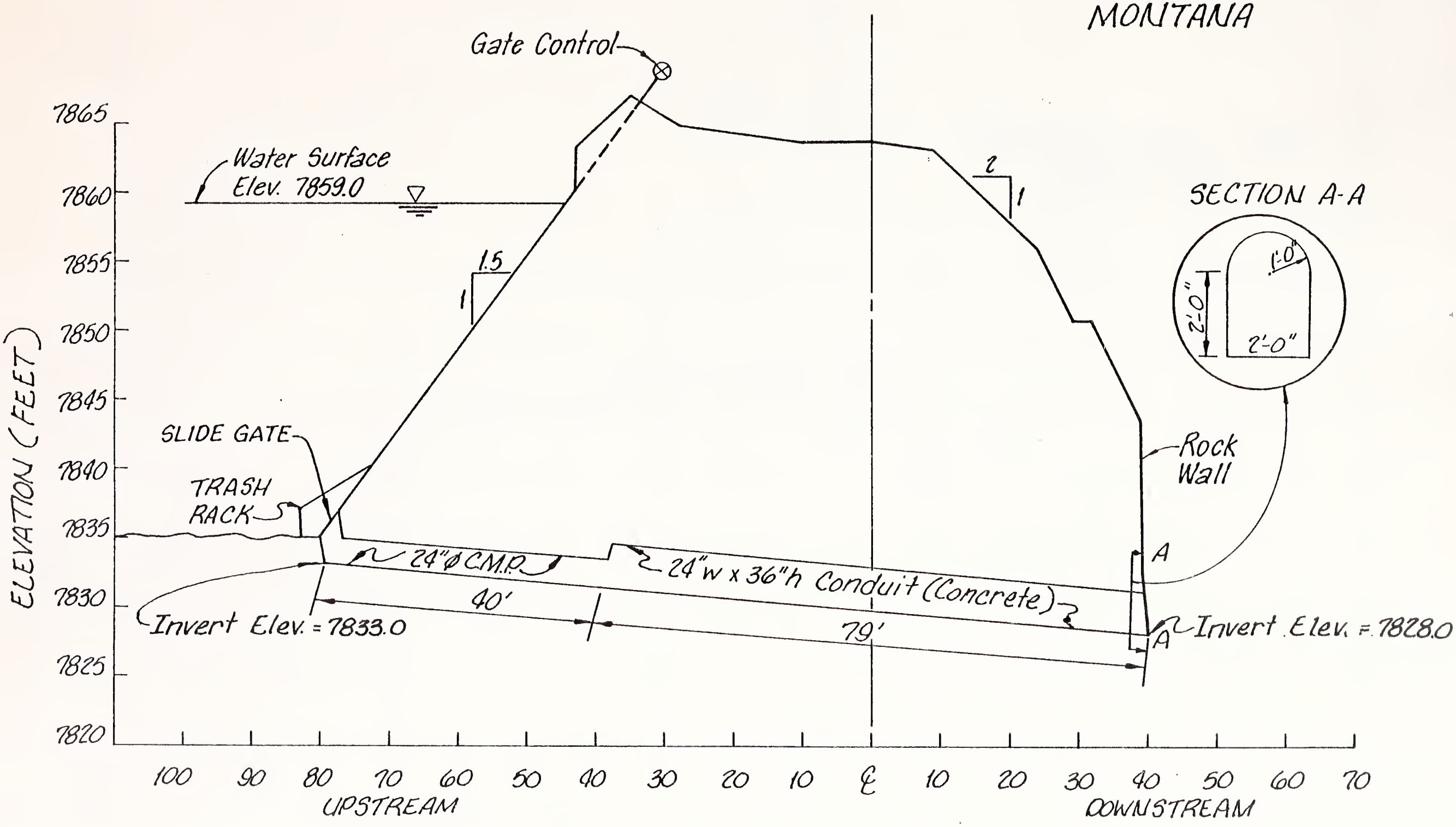
VICINITY MAP

PLATE 1

ESTLER LAKE DAM

SITE PLAN & VICINITY MAP

ESTLER LAKE DAM
MONTANA



SECTION A-A

DAM CROSS-SECTION AT OUTLET

PLATE 2

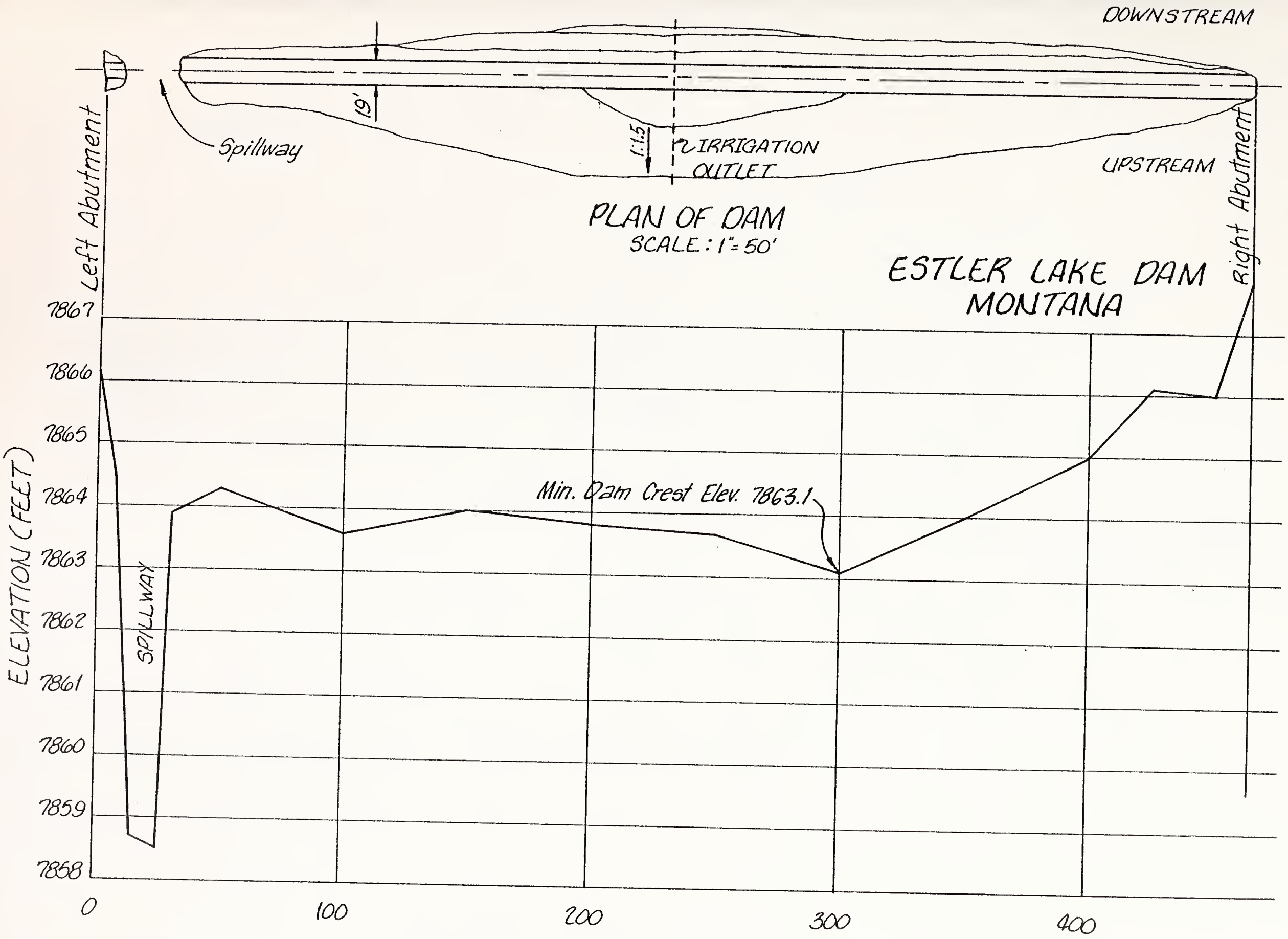
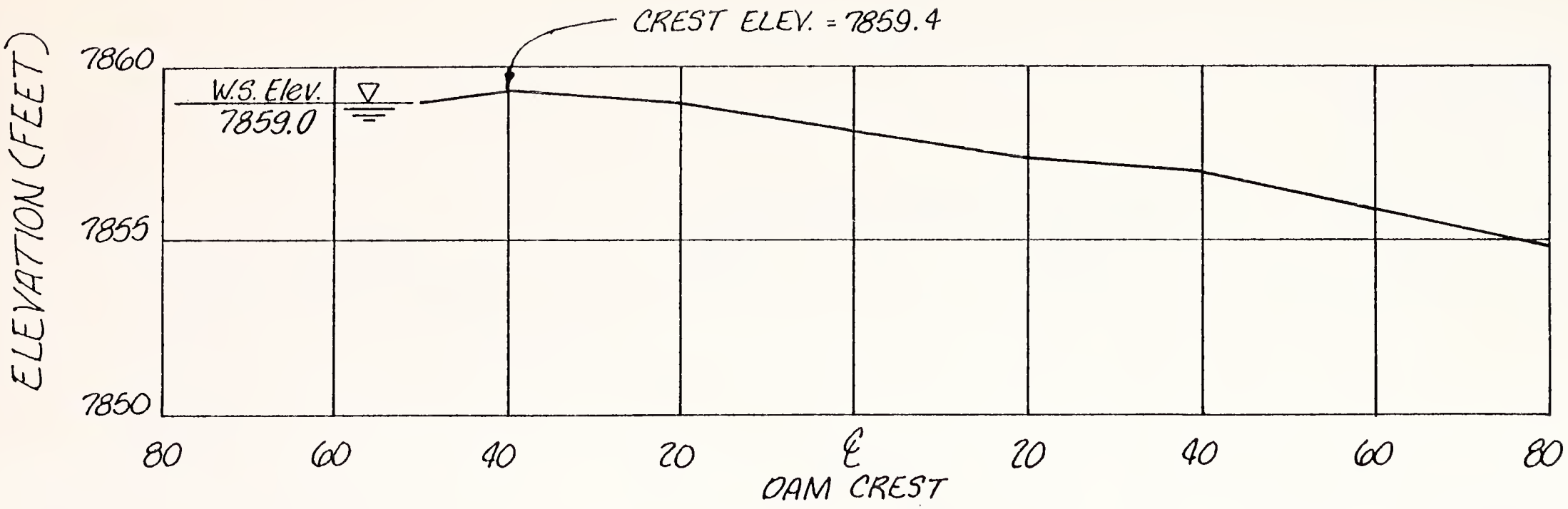

DOWNSTREAM
19'
Spillway
1:1.5
IRRIGATION OUTLET
UPSTREAM
Left Abutment
Right Abutment
PLAN OF DAM
SCALE: 1"=50'
ESTLER LAKE DAM
MONTANA
ELEVATION (FEET)
7867
7866
7865
7864
7863
7862
7861
7860
7859
7858
SPILLWAY
Min. Dam Crest Elev. 7863.1
0
100
200
300
400
DAM CENTERLINE PROFILE
SCALE: 1"=50 HORIZ.; 1"=2' VERT.

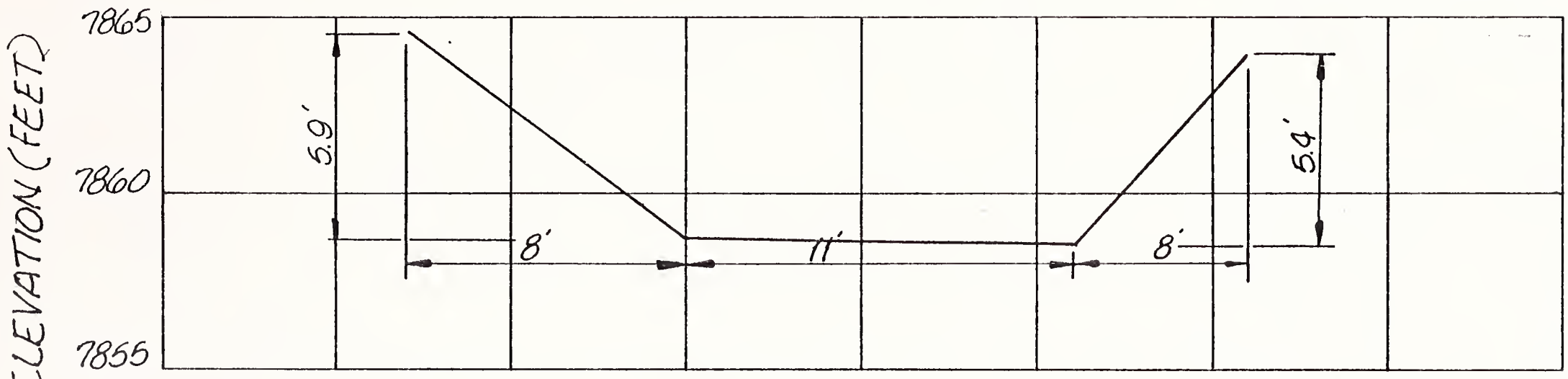
PLATE 3



SPILLWAY PROFILE

SCALE : 1"=20'(H.); 1"=5'(V.)

ESTLER LAKE DAM
MONTANA



SPILLWAY CROSS SECTION AT CREST

PLATE 4

ELEVATION - AREA & STORAGE CURVES ESTLER LAKE DAM

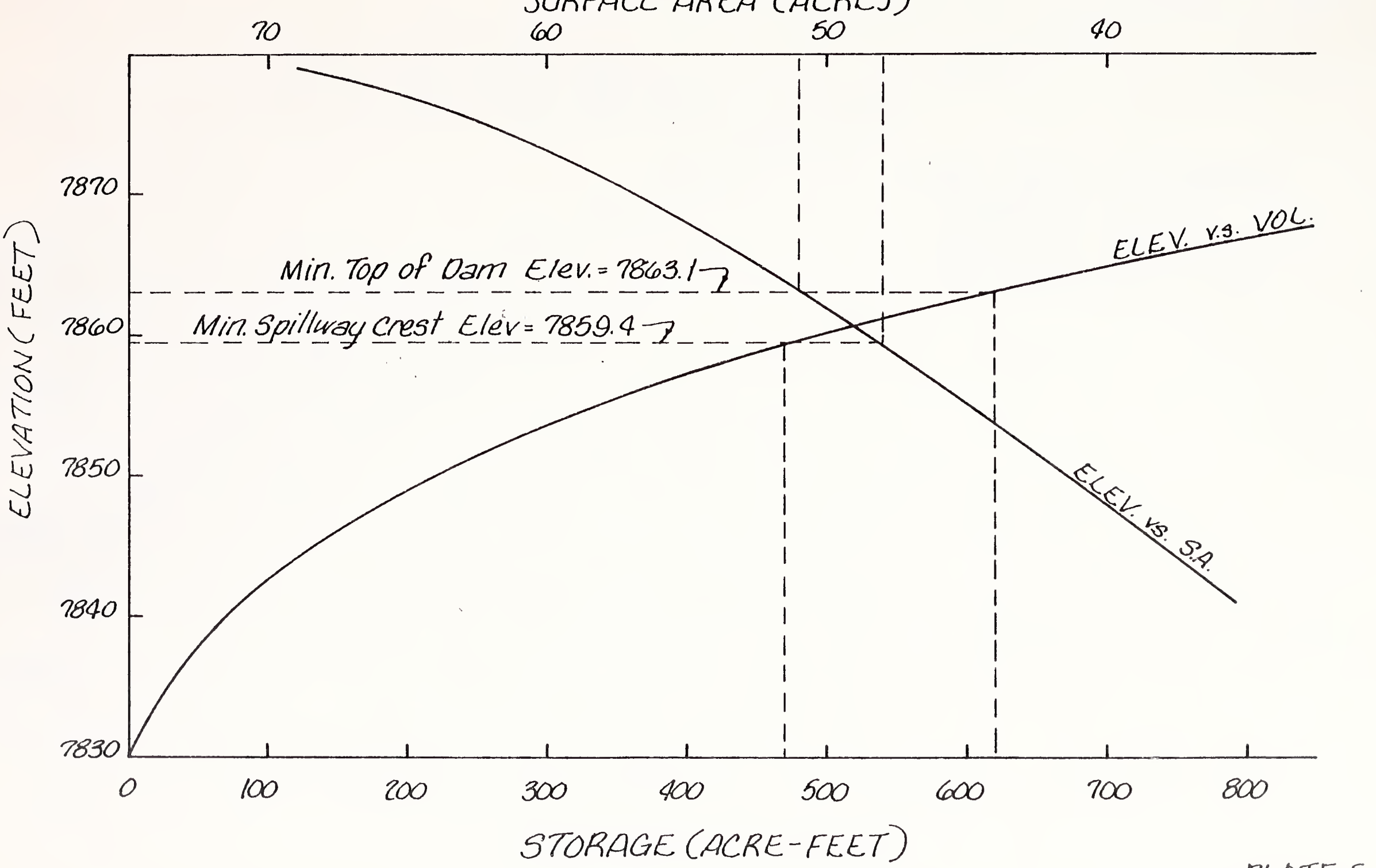


PLATE 5

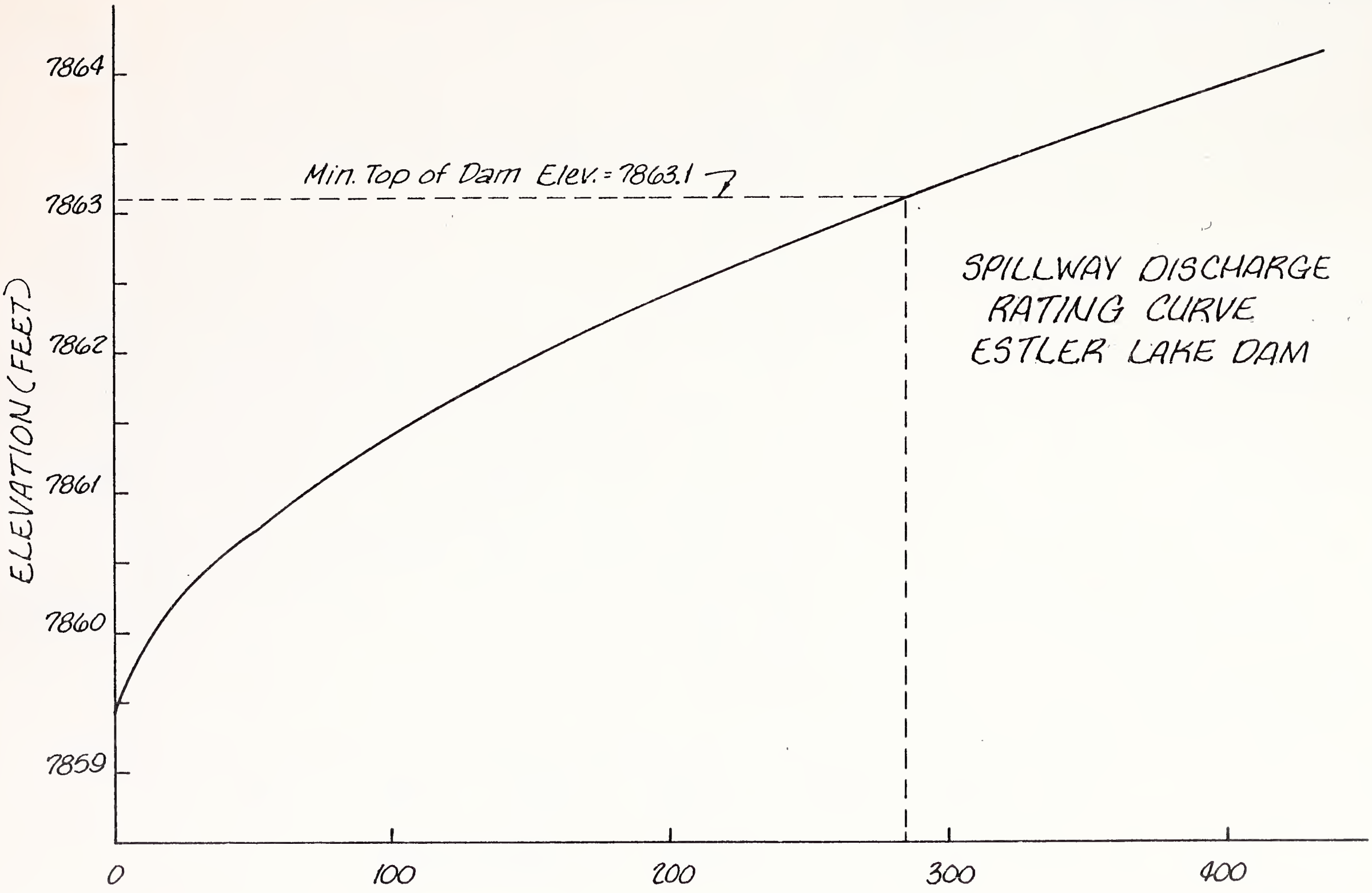

Min. Top of Dam Elev. = 7863.1
SPILLWAY DISCHARGE
RATING CURVE
ESTLER LAKE DAM
ELEVATION (FEET)
7864
7863
7862
7861
7860
7859
0
100
200
300
400
DISCHARGE (CFS)

PLATE 6

OUTLET DISCHARGE RATING CURVE
ESTLER LAKE DAM

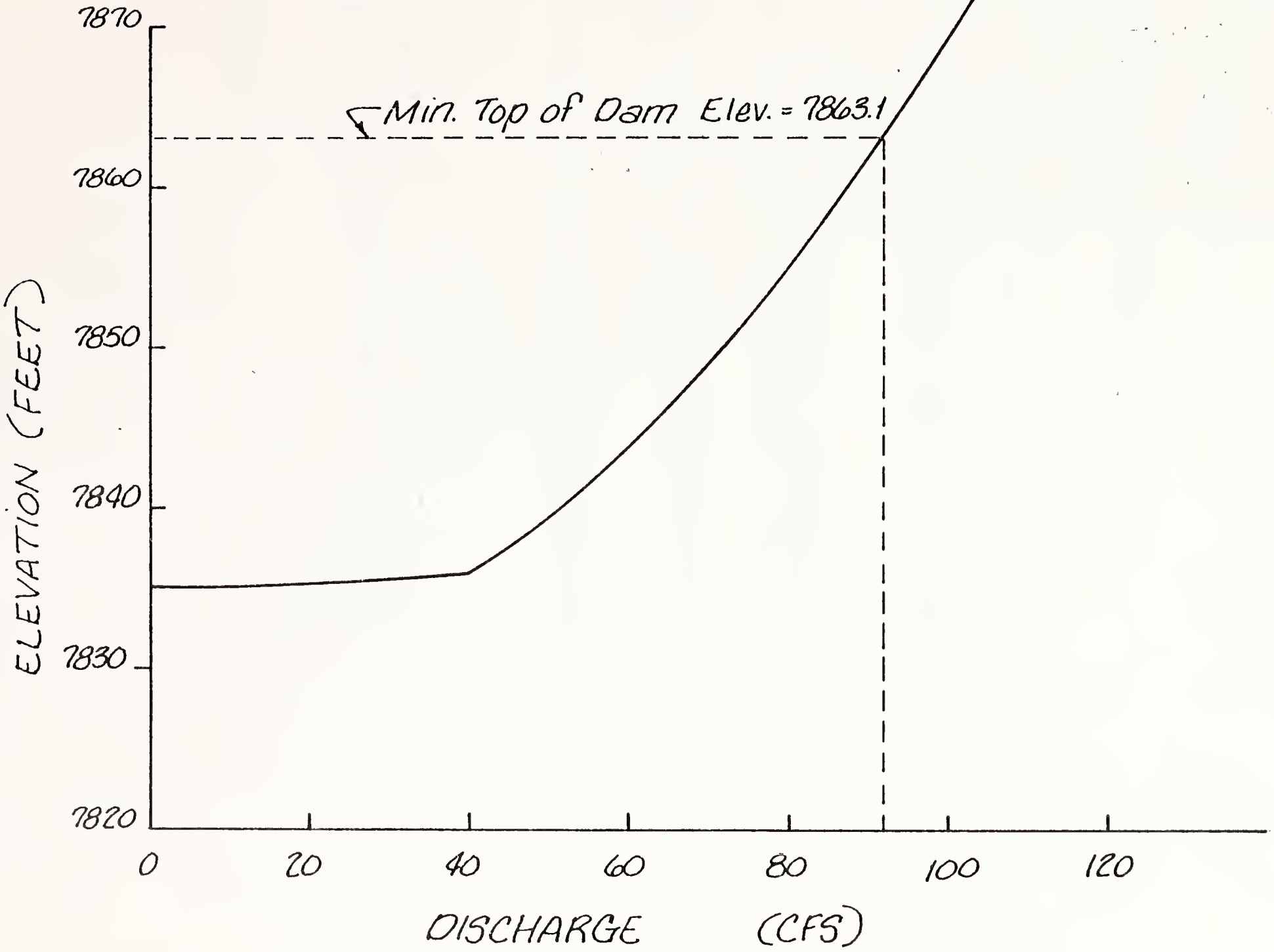


PLATE 7

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION
WATER RESOURCES DIVISION

THOMAS L. JUDGE, GOVERNOR

32 SOUTH EWING

STATE OF MONTANA

(406) 449-2872

HELENA, MONTANA 59601

December 11, 1980

Department of the Army
Seattle District, Corps of Engineers
P.O. Box C-3755
Seattle, WA 98124

Attn: Ralph Morrison

Re: Hoskins-Western-Sonderegger, Inc. Dam Safety report on Estler Lake Dam (MT-824).

Dear Ralph:

We have reviewed the above referenced final draft report. We concur with the findings and recommendations and find that it satisfies the criteria of the Phase I report.

Minor editorial comments have been discussed with your staff, and we understand these will be incorporated in the final report.

Thank you for this opportunity to review and comment on the final draft report on Estler Lake Dam.

Sincerely,

Richard L Bondy

Richard L. Bondy, P.E.
Chief, Engineering Bureau
(406) 449-2864

RB/AT/lj

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United States
Department of
Agriculture

Soil
Conservation
Service

P.O. Box 970
Bozeman, MT
59715

December 19, 1980

Sidney Knutson, P.E.
Assistant Chief
Engineering Division
Seattle District, Corp of Engineers
P.O. Box C-3755
Seattle, WA 98124

Dear Mr. Knutson:

Thank you for the opportunity to review the final draft report on Estler Lake Dam (MT-824).

We have two comments.

The last sentence on page 13 is not complete.

We do not agree with the hydrologic conditions used to develop the probable maximum flood. The conditions selected attempt to eliminate the element of risk to a degree that we feel is not practical or reasonable. Despite the climatic differences, the Omaha District appears to be imposing much more reasonable hydrologic conditions than is the Seattle District. We suggest that a common degree of risk (probability) be applied by the COE nationwide.

Sincerely,

Van K Haderlie
State Conservationist

cc:
Ray Smith, Acting State Conservation Engineer, SCS, Bozeman
Dave Jones, Environmental Engineer, SCS, Bozeman

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FEDERAL BUILDING MISSOULA, MONTANA 59801

7530

DEC 19 1980

Mr. Sidney Knutson, P.E.
Assistant Chief, Engineering Division
Seattle District Corps of Engineers
P. O. Box C-3755
Seattle, Washington 98124

Dear Mr. Knutson:

We have reviewed the final draft report for the Phase I study for Estler Lake Dam and have the following comments.

We agree a more detailed hydrologic analysis is needed to better define the hazard this dam presents.

Sincerely,

Beryl Johnston

BERYL JOHNSTON
Acting Director
Engineering

Schellack Engineering & Assoc.
Gleed Building, 30 S. Montana St.
P.O. Box 1333
Dillon, Montana 59725

—ENGINEERING SURVEYING
—FOREST SURVEYS
—MUNICIPAL ENGINEERING

LOWELL J. SCHELLACK, PE
Business - 406-683-2227
Residence - 406-683-4067

January 21, 1981

Mr. Sidney Knutson, P.E.
Department of the Army
Seattle District
Corps of Engineers
P. O. Box C-3755
Seattle, WA 98124

Dear Mr. Knutson:

I have been asked by the Rattlesnake Reservoir Company to make a response to your draft report on the Estler Lake Dam Project, inspected September 19, 1979, by your agency. I have inspected Estler Lake Dam five times in the last eight years, two times as a Federal employee and three times as a private engineer. I don't see any reference made in the report to previous inspections, which may or may not have been reviewed in making your report.

I will respond directly to your recommendations in sequential order as listed in paragraph 3.2 of the report.

1. Immediately develop, implement, and periodically test an emergency warning plan for use in the event of dam overtopping.

Action: The Company will equip the ditch rider with a two-way radio that is on the Beaverhead County Sheriff Department's frequency, to provide early warning. The ditch rider works in this drainage on a daily basis.

2. Inspect the control gate, trash rack, outlet conduit, and inlet structure, and repair as required.

Action: This is done annually by either the U.S. Forest Service or by a qualified engineer hired by the Company.

3. Remove bushes and their root systems from all embankment surfaces and from the spillway and adequately backfill the resulting holes.

Action: The Company agrees, and this is normally done during their annual maintenance work.

4. Remove and dispose of all debris from the upstream face of the dam and from the spillway.

Action: The Company agrees and this is done annually.

5. Conduct more-detailed hydraulic and hydrologic studies to better determine the downstream hazard and required spillway capacity and modify the project as studies indicate.

Action: I do not agree that this is necessary and have advised the Company to that effect. If a storm of the magnitude of 24 hour PMP occurred, it would affect more than just the watershed above Estler Lake. Such a storm would undoubtedly encompass the whole drainage above Argenta. Calculating the sole effect of Estler Lake would be guesswork at best and more than likely insignificant in relationship to the total storm.

6. Conduct an embankment stability analysis and modify the project as studies indicate. Studies should be conducted by an experienced geotechnical engineer.

Action: I do not agree that this is necessary and have advised the Company to that effect. The structure has remained stable for years. Any analysis, of any consequence, would probably require destructive testing which would, in effect, weaken the structure.

7. Develop and implement a periodic maintenance plan for the dam and appurtenant structures. Because of the remoteness of the project site, the maintenance plan should include frequent condition inspections whenever water is impounded above the natural lake level.

Action: There is already a plan in effect. The U.S. Forest Service requires annual inspection of the dam and immediate maintenance activities based on those inspections.

8. Establish a program for periodic, comprehensive, safety instructions at no more than five-year intervals. These inspections should be performed by engineers qualified in the design, construction, operation and maintenance of earth dams.

Action: There is already a program in effect which insures annual inspection by a qualified engineer.

I hope these comments and responses will be helpful in preparing your final report.

Very truly yours,

Lowell J. Schellack

Lowell J. Schellack, P.E.
Civil Engineer

bb

The Rattlesnake Reservoir Company concurs with the text of this letter as our response to your draft report on the Esler Lake Dam Project.

Esler Lake Reservoir Company

BY: _____
Ronald W. Johnson, President